



Data Article

Urban heat island data by local weather types in Lisbon metropolitan area based on Copernicus climate variables dataset for European cities

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ABSTRACT

Here we provide Urban Heat Island (UHI) by local weather types (LWT) maps for the Lisbon Metropolitan Area (LMA). These maps were produced from the Copernicus Land Monitoring Service climate variables dataset that contains hourly air temperature raster data for 100 European cities (2008–2017), namely Lisbon and part of its metropolitan area. Over 61000 maps (2008–2014) were extracted in NetCDF format and processed in geographic-information-systems (GIS). An urban mask was created from the recently updated Local Climate Zones (LCZ) classification for this area and a cell of the LCZ class “Low Plants” (non-urban) was chosen to calculate the temperature difference. UHI intensity was estimated using an R script. The outputs of this process were divided by thermal seasons and LWT. Ultimately, average UHI intensity by LWT was estimated. Average UHI according to meteorological conditions is available in GeoTIFF raster format (Appendix 1), with a spatial resolution of 100 × 100m pixels, as well as hourly average UHI for each LWT (Appendix 2 to 16). This data may provide valuable information for

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urban planners, designers and architects in the process of pinpointing recurrent hot and cool spots/neighborhoods in the city and its heating/cooling degrees. Moreover, these maps may contribute to a construction of an early warning system that anticipates which weather conditions we might expect an significant increase in thermal discomfort on those critical areas in the city.

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Specifications Table

Subject	Environmental Science
Specific subject area	Urban climatology: influence of local weather conditions on Urban Heat Island (UHI)
Type of data	Geospatial data: UHI by LWT maps
How the data were acquired	Secondary/Processed data (source of raw data: Copernicus Climate Change Service dataset with climate variables for cities in Europe from 2008 to 2017)
Data format	Geospatial analysis using a geographic-information-system (GIS) and R <i>GeoTIFF</i> raster grids at 100 × 100 m pixel resolution (.tif) <i>ArcGIS symbology layer</i> (.lyr)
Description of data collection	Acquisition of hourly raster maps in NetCDF-4 format from the online Copernicus dataset. Conversion of the data to Lisbon local time. Air temperature validation (CEG-IGOT mesoscale meteorological network). UHI estimation. Division of results by thermal seasons and LWT. Assessment of average UHI intensity and average hourly intensity by LWT.
Data source location	Institution: Copernicus Climate Change Service Region: Europe City: Lisbon Latitude (degrees): -9,14 Longitude (degrees): +38,70 Domain size (km ²): 900
Data accessibility	Repository name (raw primary data): Copernicus Climate Change Service Data identification number: DOI: 10.24381/cds.c6459d3a Direct URL to data: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-urban-climate-cities?tab=overview Repository name: Mendeley Data Data identification number: DOI: 10.17632/ypff9pyb6z.1 Direct URL to data: https://data.mendeley.com/datasets/ypff9pyb6z/1
Related research article	C. Reis, A. Lopes, A. Nouri, Assessing Urban Heat Island effects through Local Weather Types in Lisbon's Metropolitan Area using Big Data from the Copernicus Service, Urban Climate 43 (2022) 101168. https://doi.org/10.1016/j.uclim.2022.101168

Value of the Data

- The maps of UHI intensity by LWT provide new insights to previous research about Lisbon's UHI undertaken during the last 40 years [1–6], especially concerning the influence of local weather conditions on UHI intensity and pattern.
- The data can be quite useful for stakeholders, especially urban planners, designers and architects that are involved on the identification of critical heating urban canyons and the weather conditions most prone to higher UHI values and, hence, thermal discomfort conditions, considering also the negative of future climate projections. These future scenarios translate into a significant increase in air temperature, as well as more frequent, intense and durable heat wave events [7].
- Additionally, the analysis of UHI by LWT may help the creation of an early warning system connected to the national/regional meteorological services, anticipating weather conditions

with high heating potential, especially on those critical areas/neighborhoods of the city and structuring an action plan with a set of measures to protect vulnerable populations to excessive heating conditions, such as the elderly, individuals with pre-existing cardiovascular pathologies and children.

- Last, but not least, these maps are a fundamental tool for future investigation about the main drivers of the different behavior of UHI intensity in all phases of its daily cycle according to weather conditions.

1. Data Description

The application of a LWT classification to the analysis of UHI thermal patterns is still a pioneer work in urban climate studies. These LWT were defined by thermal seasons, which differ substantially from traditional astronomical divisions of the year. Detailed information about these thermal seasons is available on [8]. Additionally, detailed information about the LWT classification is provided on [8] and the full description of each daily LWT can be found on [9]. Fifteen raster *GeoTIFF* maps (Appendix 1) depicting UHI intensity by LWT in LMA are presented here. Additionally, for each LWT, twenty-four hourly average UHI raster *GeoTIFF* maps are provided for each LWT (Appendix 2 to 16). The contents of each map, are described as follows:

- Thermal summer
 - raster *GeoTIFF* maps with the name “SUMild_cloudy” represent average UHI on mild, cloudy and humid days with light rain and moderate NW winds, which occur in about 15% of days.
 - raster *GeoTIFF* maps with the name “SUMildNW” depict average UHI on mild, sunny and humid days with moderate NW and N winds, which are frequent in 26% of the thermal summer.
 - Raster *GeoTIFF* grids with the name “SUMildN” represent average UHI intensity on mild, sunny and humid days with strong N winds (23% of days).
 - Raster *GeoTIFF* maps with the name “SUhot” indicate average UHI on hot, sunny and humid summer days with moderate N winds (only on 6% of thermal summer days).
 - Raster *GeoTIFF* maps with the name “SUvhot” depict average UHI on very hot, sunny and humid days with moderate N winds (21% of days).
- Thermal winter
 - Raster *GeoTIFF* maps with the name “WcoldN” indicate average UHI on cold, cloudy and dry days with weak and variable winds, specially from N and NW (29% of days).
 - Raster *GeoTIFF* grids with the name “WcoldSW” depict average UHI on cold, cloudy, rainy and dry days with moderate SW and W winds (7% of winter days).
 - Raster *GeoTIFF* maps with the name “WvcoldN” represent average UHI on very cold, sunny and dry with moderate N winds (26% of days).
 - Raster *GeoTIFF* maps with the name “WvcoldNE” represent average UHI on Very cold, sunny and dry with weak NE, E and N winds (22% of days).
- Thermal spring
 - Raster *GeoTIFF* maps with the name “ScoldNW” represent average UHI on cold, cloudy and dry days with weak precipitation and moderate and variable winds, specially from NW, SW and W (29% of days).
 - Raster *GeoTIFF* maps with the name “ScoldN” depict average UHI on cold with moderate cloud coverage, dry and with moderate N winds (28% of days).
 - Raster *GeoTIFF* maps with the name “Smild” indicate average UHI on mild, sunny and humid spring days with moderate N winds (22% of days).
- Thermal autumn
 - Raster *GeoTIFF* grids with the name “Acold” indicate average UHI on cold, with moderate cloud cover and dry days with moderate N and NE winds (23% of days).

- o Raster *GeoTIFF* maps with the name “Acool” indicate average UHI on cool, cloudy, humid and rainy days with moderate SW and W winds (10% of days).
- o Raster *GeoTIFF* maps with the name “Amild” represent average UHI on mild, with moderate cloud cover, humid, with possibility of rain and weak N, NE and S winds (21% of days).

Raster *GeoTIFF* maps representing hourly average UHI intensity by LWT share the same name but end with the respective hour of the day (example: “SUMild_cloudy_1am” - hourly average UHI intensity at 1 am on mild, cloudy and humid summer days; “SUMildNW_4pm” - hourly average UHI intensity at 4 pm on mild, sunny and humid summer days). The twenty-four hourly average UHI maps by LWT are grouped into Appendix 2 to 16, one per LWT.

- o Appendix 2 contains the twenty-four UHI maps for “SUMild_cloudy” LWT.
- o Appendix 3 contains the twenty-four UHI maps for “SUMildNW” LWT.
- o Appendix 4 contains the twenty-four UHI maps for “SUMildN” LWT.
- o Appendix 5 contains the twenty-four UHI maps for “SUhot” LWT.
- o Appendix 6 contains the twenty-four UHI maps for “SUvhot” LWT.
- o Appendix 7 contains the twenty-four UHI maps for “WcoldN” LWT.
- o Appendix 8 contains the twenty-four UHI maps for “WcoldSW” LWT.
- o Appendix 9 contains the twenty-four UHI maps for “WvcoldN” LWT.
- o Appendix 10 contains the twenty-four UHI maps for “WvcoldNE” LWT.
- o Appendix 11 contains the twenty-four UHI maps for “ScoldNW” LWT.
- o Appendix 12 contains the twenty-four UHI maps for “ScoldN” LWT.
- o Appendix 13 contains the twenty-four UHI maps for “Smild” LWT.
- o Appendix 14 contains the twenty-four UHI maps for “Acool” LWT.
- o Appendix 15 contains the twenty-four UHI maps for “Amild” LWT.

An ArcGIS symbology layer (*.lyr), named “UHI_symbology”, is also provided and can be applied to all UHI maps.

2. Experimental Design, Materials and Methods

2.1. Input data

The average UHI intensity maps by LWT were produced using a climate variables dataset from the Copernicus Climate Change Service (<https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-urban-climate-cities?tab=overview>). This dataset contains hourly air temperature, specific humidity, relative humidity and wind speed data for 100 European cities (2008 to 2017), including Lisbon and part of its metropolitan area, with a reasonable spatial resolution (100 × 100m). Only the air temperature files (2m above ground) were used in this study. Table 1 (Table 4 of the original research article – [9]) synthesizes this data details.

Table 1
Copernicus air temperature hourly data (Lisbon): description – Reis et al [9]

Variable	Air temperature (2m above surface)
Unit	K
Data Type	Gridded
Horizontal Coverage	European
Temporal coverage	2008-2017 (extracted only 2008 to 2014)
Horizontal resolution	100m * 100m
Temporal resolution	Hourly
Time Format	UTC
File Format	NetCDF-4

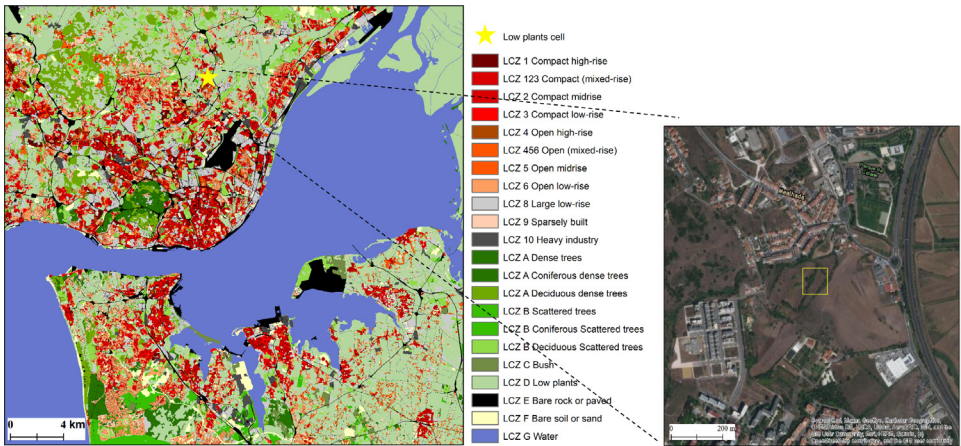


Fig. 1. LMA's updated LCZ [11] and location of the non-urban site [9].

Only the hourly maps for Lisbon between 2008 to 2014 were extracted from this dataset, which comprises 61368 NetCDF-4 air temperature files, 20190 (32,9%) for the thermal summer, 16814 (27,4%) for the thermal winter, 16447 (26,8%) for spring and 7917 (12,9%) for autumn.

2.2. Air temperature validation and UHI assessment

The hourly air temperature records from Copernicus dataset were validated against a mesoscale meteorological network that operated in Lisbon between 2004 and 2014 with nine different measuring points recording air temperature every 15 minutes at 3,5 m height [2,4]. Therefore, modeled air temperature was extracted for seven of the nine measuring points of the CEG-IGOT network and correlations between pairs (modeled against measured) were calculated along with some paired sample t-Tests. Detailed description of this validation procedures and results can be found on [9].

All 61368 Copernicus air temperature maps were divided by thermal seasons and LWT. In order to identify urban cells in the Copernicus window that covers a significant portion of LMA, an urban mask was create using LCZ 1 to 10 classes (1 – Compact high-rise; 2 – Compact midrise; 3 – Compact low-rise; 4 – Open high-rise; 5 – Open midrise; 6 – Open low-rise; 8 – Large low-rise; 9 – Sparsely built; 10 – Heavy industry). This standard typification of Land Cover/Land Use classes, according to their climatic response has been extensively use in urban climate studies and it was recently updated for this study area by [10,11]. Additionally, a raster cell from the LCZ D class (Low plants) was chosen as a non-urban site. It is located at N of the Lisbon's county boundaries (Fig. 1, which corresponds to Fig. 4 in the original research article, [9]), especially at N of the Lisbon's Airport weather station, which has been considered a reference site for UHI studies over the past decades [1,2,4,5,12]. Non-urban areas represent over 84% of the LMA, especially LCZ D, which covers about 43% of the total area (1767 m^2 - [10]).

Since the air temperature data format was in NetCDF-4, all files were converted to raster format (.tif) in ArcGIS (version 10.7.1.). Sequentially, hourly UHI intensity between 2008 and 2014 was calculated in R (version 4.1.0.), according to the following equation:

$$\text{UHI}_{t\text{COP}} = T_{\text{Urb}} - T_{\text{NUrb}} \quad (1)$$

$\text{UHI}_{t\text{COP}}$ indicates UHI intensity at each raster cell at time t, obtained from air temperature Copernicus dataset;

T_{Urb} represents air temperature of each urban cell in Copernicus grid at time t and;

T_{NUrb} represents the air temperature at a non-urban location (raster cell from LCZ D “Low Plants” class – Fig. 1).

Ultimately, average UHI by LWT was calculated in *ArcGIS* using all hourly UHI generated files from days belonging to each particular set of meteorological conditions. Furthermore, hourly average UHI per LWT was also estimated in order to analyze the UHI daily cycle considering different meteorological conditions.

Ethics Statement

The authors declare that the work did not involve the use of human subjects, animal experiments or information from social media sources.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Urban Heat Island (UHI) by Local Weather Types (LWT) maps for Lisbon Metropolitan Area (LMA) (Original data) (Mendeley Data).

CRedit Author Statement

Cláudia Reis: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Writing – original draft, Visualization; **António Lopes:** Conceptualization, Methodology, Software, Validation, Resources, Supervision, Writing – review & editing; **A. Santos Nouri:** Supervision, Writing – review & editing.

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